BLOOD AND BLOOD STAINS IN MEDICAL JURISPRUDENCE.*

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The public interest aroused in recent criminal trials, where the identification of blood and blood stains became an important subject of inquiry, has led me to bring to the attention of medico-legal jurists and the general public the present state of scientific knowledge bearing upon this subject, with the decisions of the courts regarding it, for the purpose of showing as well what can be ascertained by scientific inquiry as to discriminating between human blood and that of other animals as to illustrate in a familiar way what is now known and can be demonstrated by science, with the methods employed by the most skillful, in deciding such questions so as to make it easily understood by all intelligent persons.

Blood.

Blood in all vertebrate animals consists of small corpuscular structures floating in what has been called blood plasma or *Liquor sanguinis*, sometimes called blood serum. These consist of red corpuscles, white corpuscles, and blood plates, so called.

The Red Corpuscles.

The red blood corpuscles afford the best means and the most interesting study of these questions in forensic medicine by the microscope and the micrometer.

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*Read before the Medico-Legal Society, May session, 1892.

Read before the American Microscopical Society at Rochester, August 11, 1892.

On account of the length of this article an abstract only, with most of the plates, is here published. The entire paper, which is an elaborate survey of the subject, will be found in the Medico-Legal Journal of September, 1892. The Society is very much indebted to Mr. Bell for the loan of the numerous cuts which illustrate the article.—W. H. S.

Swammerdam first saw them in the blood of the frog in 1658, Malpighi in that of the hedgehog in 1661, and Leeuwenhock in the blood of man in 1673. Perhaps no subject in Morphology has been more carefully studied, but up to the present time we have learned comparatively nothing of the structural arrangement of the red blood corpuscles, nor can we explain any considerable number of the phenomena which they display.

Form, Color, and Structure.

Two distinct forms have been discovered in the red corpuscles of blood:

1. The circular disc depressed in the center occurs in all the mammals except the camel and auchenia.

2. The elliptical or oval discs with central prominence are seen in the blood of all birds, amphibia, most fishes, and of mammals, the camel, and the auchenia. The microscope enables the observer to distinguish the blood of birds, fishes, and reptiles from mammalian blood (which includes that of the human being) by the organic structural difference in form.

There are three kinds of blood corpuscles: the red, which I shall chiefly consider in this paper; the white corpuscle, and the so-called blood plates, the latter having been only recently discovered by Hayem in 1878.* *Vide* his article on blood in his Klienische Microscopic, 1887; also Virchow's Archiv, 1882, Bd. 90, p. 261.

These blood plates are demonstrated to be the important factors in the clotting of blood. Studies of these blood plates have been made by William Osler, and by him published in the Philadelphia Medical Times of April 3 and October 17, 1886, and by Welch. *Vide* "The Structure of the White Thrombi:" Transactions of the Pathological Society of Philadelphia, vol. xiii (1887). They number about one-twentieth part of the blood corpuscles.

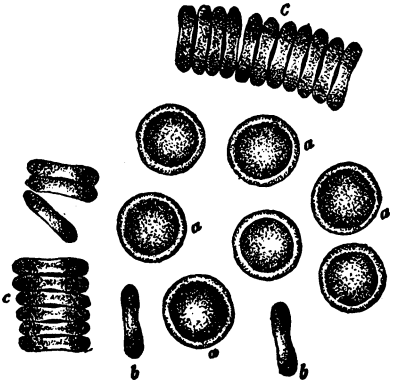
The white corpuscles are few in number, averaging only about one to five hundred of the red corpuscles. They are spherical in shape, of a pale, milky appearance, have a peculiar amœboid motion, and assume varied shapes. They also have nuclei. They are of a comparatively uniform size in all vertebrates, being from $\frac{1}{2700}$ to $\frac{1}{3000}$ of an inch in diameter, so that a contrast of their diameters throws no light upon the present inquiry.

* Recherches Sur l'Anatomie Norm et path du sang, by Hayem, Paris, 1879. Comptes Rendus de l'Academie de Sci., 1882, 18 Julie, and by Bizzozero in 1882.

Professor Formad claimed that the white blood corpuscles are the progenitors of the red ones.

So far as present scientific knowledge goes, they furnish no source of information in discriminating between the blood of man and other animals.

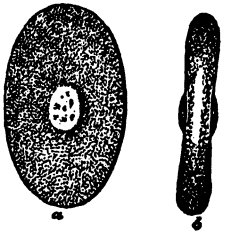
Fig 1.



Red Blood Corpuscles.

a. Flat side presented. *b*. Single side view presented
c. In rouleaux like coin.

Fig. 2.



a. Side view of oval disk. *b*. End view, showing nucleus.

White Corpuscles and Blood Plates.

The specific gravity of the red corpuscles is stated by high authorities to be about 1088; that of serum 1028.

Dana has calculated that the ratio of the weight of the total bulk of blood to the total weight of the body is in man 1–13, and the

same in the dog, but less in other domestic animals—the cat, 1–14; horse, 1–15; rabbit, 1–18; guinea-pig, 1–19; calf, 1–21; sheep, 1–24; pig, 1–26; ox, 1–29.

Formad claims, from his own researches made upon red blood corpuscles, that they have in fact no nuclei; that they are not actually red but yellow; that the apparent nucleation is due to their biconcavity, on account of which the center of the corpuscle appears dark in one focus with a light periphery, while in another focus the reverse occurs.

He also claims to have demonstrated by the test of the venom of serpents that they have no cell wall or membrane, and that, in fact, what seems a cell wall or membrane is only the outer hardened layer of the protoplasm of the corpuscle.

Three methods of investigating blood have been employed by scientific observers, viz:

1. Chemistry.
2. The spectroscope.
3. The microscope and its allies, the micrometer and the microphotograph.

Chemistry.

The highest chemical authorities unite in the statement that there are no ascertained chemical differences between the blood of man and that of other animals.

The Guaiacum Test.

This test is thus made: Take the tincture of guaiacum, dissolve it in rectified spirits of wine, and add peroxide of hydrogen dissolved in ether.

If in this is dropped a solution containing blood it will turn the tincture blue in a few seconds. While there are several organic substances that will turn guaiacum blue, still this is a practical and valuable test. The force of the experiment lies in the fact that while blood alone will not blue guaiacum, in the presence of ozonized ether (peroxide of hydrogen dissolved in ether) the blue color at once appears.

Hæmatin Crystals.

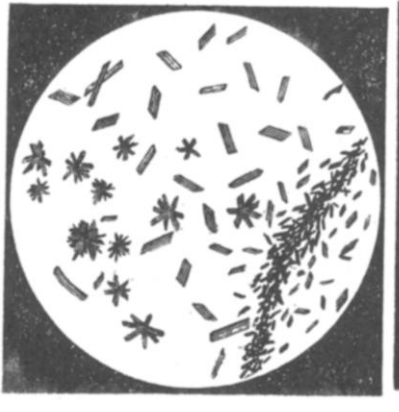
Take a blood clot, or fragment of one, and evaporate it to dryness, with an excess of hæmatin (hydrochloride of hæmatin) and a trace of chloride of sodium. Then add more acetic acid and re-

peat the evaporation, but more slowly. Then examine the residuum under a microscope of at least 300 to 500-diameter power. Crystals will be formed of well-known and well-defined character and shape.

Figures B and C are examples of these crystals, which I am permitted by Prof. Theodore G. Wormley, of Philadelphia, to use, from his work, Micro-Chemistry of Poisons.

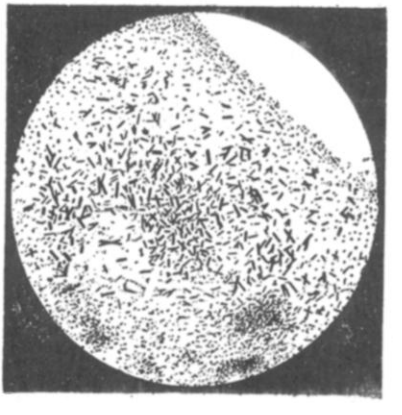
This test has been called "Teichman's Crystals," after its discoverer. Formad says it can be relied upon as indicating *the presence* of blood, but cannot be relied upon as indicating *the kind* of blood.

Fig B



Hæmatin Hydrochloride. × 400 diameters.

Fig C.



Hæmatin Hydrochloride from 1-500 grain of blood. × 750 diameters.

Professor Tidy describes these crystals and this test as "Teichman's Test as modified by Neuman." He says:

"Thoroughly rub together the dried blood and common salt. Treat the mixture with glacial acetic acid, and cautiously evaporate the solution until solidification commences.

"Cool the slide rapidly and examine with ¼-inch objective, when crystals of hæmatin (browish black or reddish brown rhomboids, or tabular crystals), together with crystals of sodic chloride (transparent tubes) will be apparent.

"The experiment may also be made without employing sodic chloride. (Casper.)

"In the case of a stain it should be placed on a glass slide and moistened with a solution of sodic chloride.

"It should then be covered over with a large thin glass, and glacial

acetic acid allowed to run under the edge. The liquid is then to be heated to dryness at a boiling temperature, and the slide allowed to cool. When cold, rhomboidal crystals of hydrochlorate of hæmatin, together with crystals of sodic chloride, dispersed through irregularly shaped albuminous masses, will be seen.

"It is stated that the character of the network in which the crystals are dispersed varies with different animals, forming characteristic pictures." (American Journal Medical Science, lx, p. 42; 1 Tidy Legal Medicine, p. 222.)

Spectral Analysis.

Sorby says that a spot of blood of only one-tenth of an inch in diameter or a quantity of red coloring matter equal to only the 10000th part of a grain was sufficient to give conclusive evidence of the presence of blood by spectral analysis; and the late Dr. Richardson, of Philadelphia, stated that he was able, by a still more delicate process, to detect the 30000th part of a grain of blood on an axe handle supposed to have been used in a case of murder.*

The Microscope and its Powers.

We have shown how readily mammalian blood can be distinguished from the oval and nucleated corpuscles by this marvelous instrument.

It was claimed by Taylor, one of the highest authorities, that, in his day, no certain method existed of distinguishing human from other mammalian blood when it had been once dried on an article of clothing or upon a weapon, and his editors have, since his death, made the same claim. (Taylor, 12th London Edition, p. 279.)

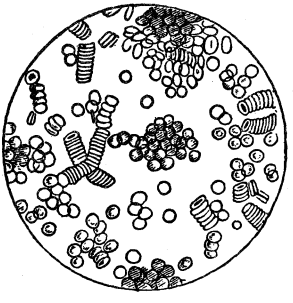
The learned editor of Taylor's Medical Jurisprudence, to whom I refer, Dr. Thomas Stevenson, of London, quotes in the same volume approvingly the valuable labors of Dr. Richardson, of Philadelphia, as reported in American Journal of the Medical Sciences, July, 1874, that by the use of the microscope of higher powers, up to 750 diameters, and by other appliances he had been able to distinguish, under favorable conditions, the blood of man from such animals as the ox and pig and to give evidence thereon in certain trials for murder. Taylor and other observers before Richardson had only used 300 to 800 diameter powers. *Vide* Figs. 3 and 4.

*See for description of this test Taylor's Manual of Medical Jurisprudence, 12th London ed., 272.

The method is to contrast the diameters of the red blood corpuscles of man with each of the mammalian animals.

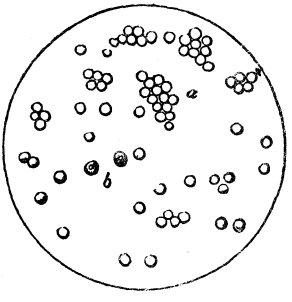
The diameter of the red corpuscle of each mammal has been ascertained approximately by averages. The difficulty lies in the

Fig. 3.



Red Blood Corpuscles, 315 diameters.

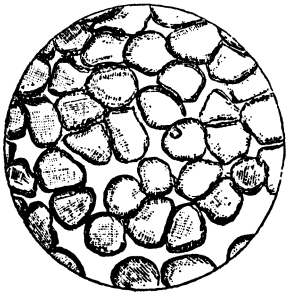
Fig. 4.



a. Red Blood Corpuscles, 315 diameters.
b. White Corpuscles.

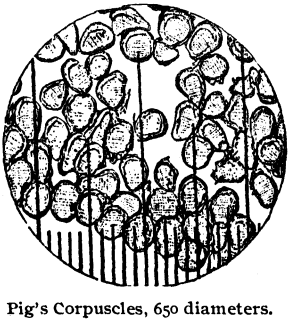
exactness of the standard. For example, the average diameter of the human red blood corpuscle is $\frac{1}{3200}$ of an inch. *Vide* Fig. 5. Reese says the maximum is $\frac{1}{2000}$; minimum, $\frac{1}{4000}$. Dr. Stevenson places the maximum at $\frac{1}{3000}$ and the minimum $\frac{1}{5000}$ of an inch.

Fig. 5.



Human Corpuscles, 650 diameters.
1-3500, Dr. Seiler's measurements,
Amer. Med. Times, Feb'y, 1876.

Fig. 6.



Pig's Corpuscles, 650 diameters.
1-4250, Dr. Seiler's measurements.

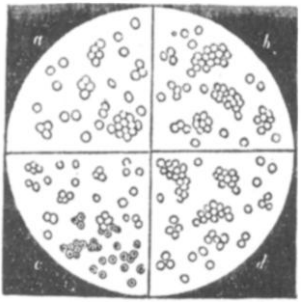
Gulliver, a high authority, places the average human red corpuscle $\frac{1}{3200}$. The Medico-Legal Society of France, in 1873, $\frac{1}{3257}$; Wormley, $\frac{1}{3250}$; Masson, $\frac{1}{3257}$; Formad, in 1888, $\frac{1}{3200}$.

All unite in the statement that the human corpuscle is larger than those of the domestic animals. These are measurements upon fresh blood, which has not been allowed to dry on animal or vegetable stuffs.

Fig. 7.

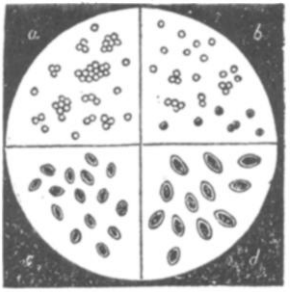
Red Blood Corpuscles magnified 319 diameters.
a. The Dog. *b*. The Mouse.
c. The Rabbit. *d*. The Ass.

Fig. 8.



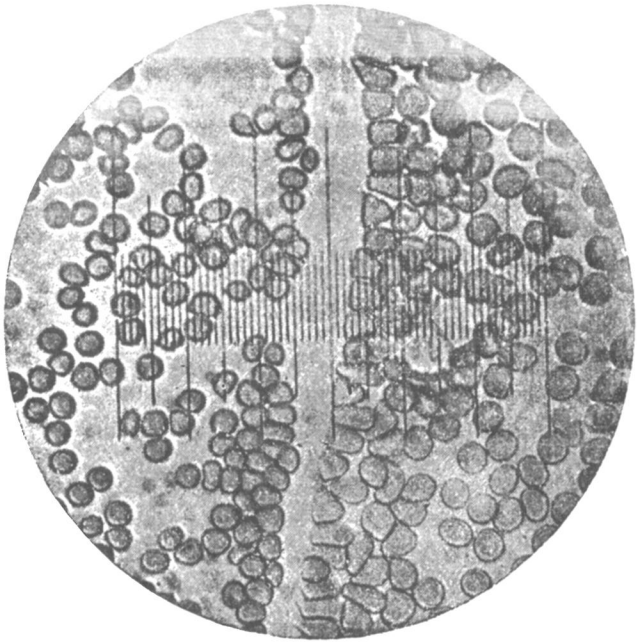
Red Blood Corpuscles magnified 319 diameters.
a. The Cow. *b*. The Dog.
c. The Ox. *d*. The Cat.

Fig. 9



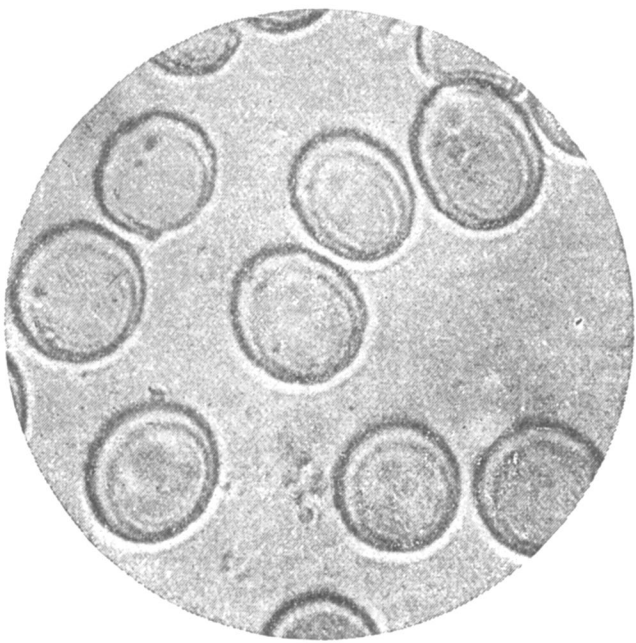
Red Blood Corpuscles magnified 319 diameters.
a. The Horse *b*. The Sheep.
c. Common Fowl. *d*. Salamander.

The average diameter of the red corpuscles of the blood of the sheep is $\frac{1}{5000}$; the goat, $\frac{1}{6366}$, and these are so much smaller than those of man that a microscope of low power would certainly discriminate them by the size of the red corpuscle from those of man, as also those of the horse, $\frac{1}{4600}$; the cow, $\frac{1}{4500}$; the cat, $\frac{1}{4004}$; the pig, $\frac{1}{4230}$, and the mouse, $\frac{1}{3814}$. (*Vide* Figs. 7, 8, 9.)



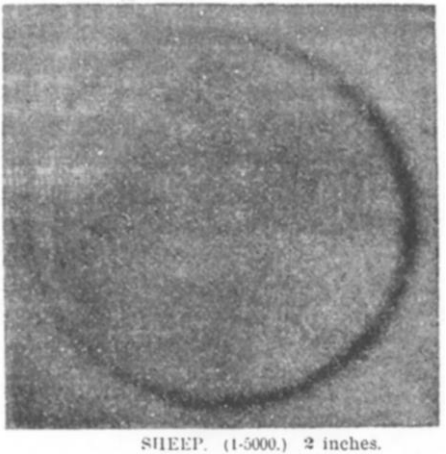
OX AND HUMAN

Blood Corpuscles Side by Side. Magnified 500 Diameters. Micrometry Illustrated. Photo-Micrograph by Dr. Seiler.



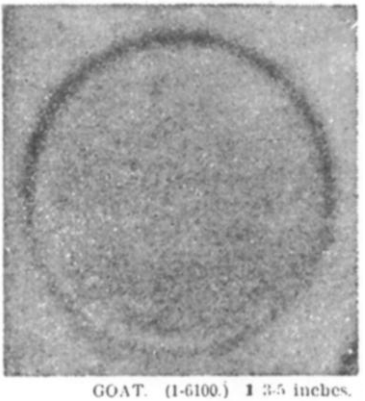
FRESH HUMAN BLOOD. Red Blood Corpuscles, Magnified 2250 Diameters. Photo-Micrograph. 1-18 Zeiss Hom Oil Immersion and Projection Eye-Piece.

The greater difficulty arises with those animals whose red corpuscles approximate nearer in size to those of man, such as the dog.



SHEEP. (1-5000.) 2 inches.

Taylor says the average diameter of the red blood corpuscles of the dog are $\frac{1}{3540}$; Reese, $\frac{1}{3500}$; Formad, $\frac{1}{3580}$; Wormley, $\frac{1}{3561}$; Gulliver, $\frac{1}{3532}$.*



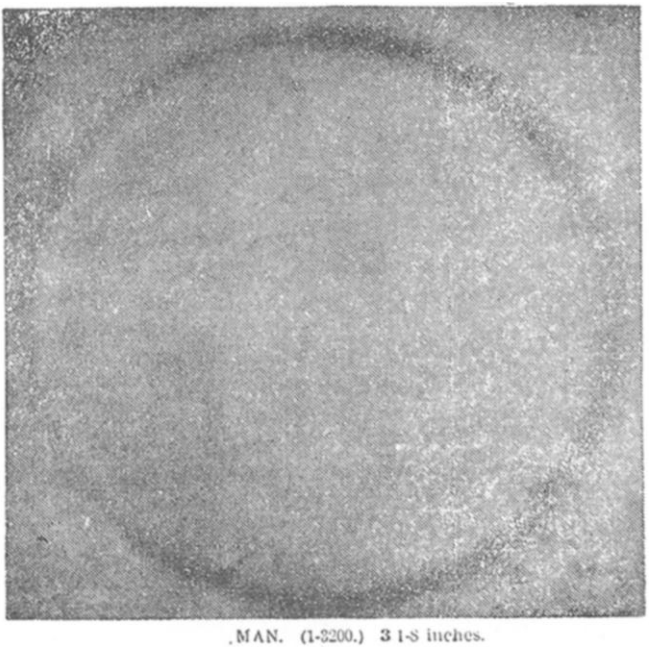
GOAT. (1-6100.) 1 3-5 inches.

The studies of Professor Formad, of Philadelphia, are perhaps of as great interest as those of any recent observer, especially with high

*See President's Address, William J. Lewis, these Proceedings, 1889, on this subject.

powers. His method with dried blood is first to expose it to a gentle, moist heat from one to ten days, according to the age of the stain.

"A small granule of the suspected blood on a fiber from the blood-stained fabric is placed on a glass slide in a drop of 30 to 35 per cent. solution of caustic potash and covered with a glass slide. If the blood stain was recent, the disintegration of the clot commences at once, and the isolated corpuscles separate and swim swiftly through the liquid if the stage of the microscope is slightly inclined."



.MAN. (1-3200.) 3 1-8 inches.

Professor Formad has recently claimed that by a still higher amplification, obtained by rephotographing single corpuscles of different animals (prepared in the same manner as Professor Richardson's and under similar projections), he has secured most singular and striking results.

Thus, by enlargement to 10,000 diameters, Formad claims to have obtained the following photographic measurements: The human corpuscles, enlarged to 3⅛ inches in diameter; guinea-pig, 3 inches; dog, 2⅘ inches, ox, 2⅓ inches; sheep, 2 inches; goat,

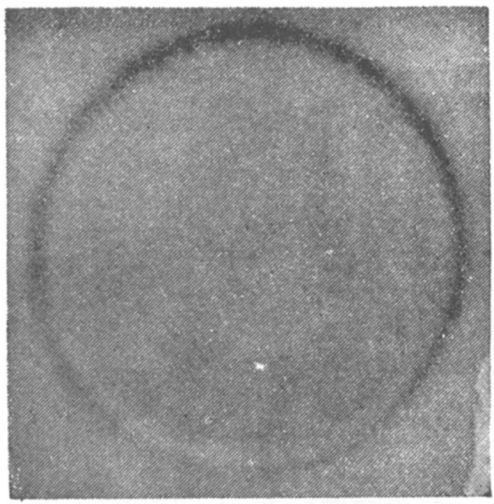
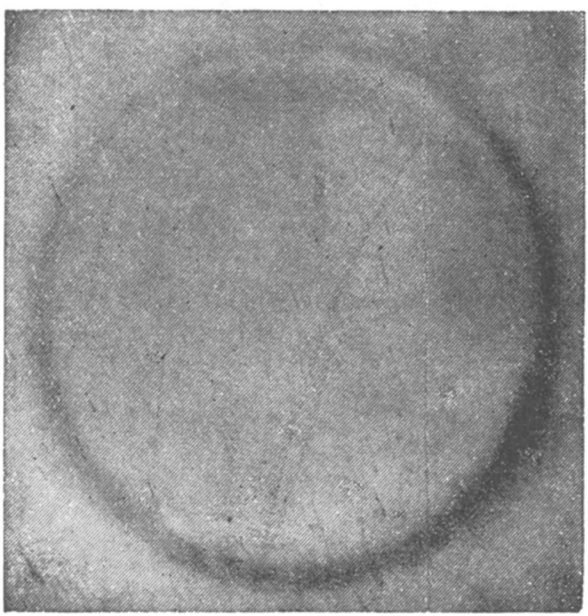


FIG. 10. . OX. (1-4200.) 2 1·3 inches



DOG. (1-3500.) 2 4·5 inches

1⅜ inches. Under such tests, and the light thrown upon the subject by these able observers, with these very high powers, the careful observer would, as he claims, be able to state that the corpuscles were *not* those of the sheep, the goat, the horse, the cow or ox, and probably the dog, as well as most of the mammals, except the guinea-pig and opossum.

The tables of Professor Wormley as to the average diameter of the red corpuscles of the mammalia may be quoted as of high value. He has made illustrations of the apparent size of red corpuscles, under an amplification of 1,150 diameters, expressing the average diameters in vulgar fractions, thus—3,250 equals $\frac{1}{3250}$ of an inch. This table of illustration shows the corpuscles of man, the dog, mouse, ox, sheep, and goat.

BLOOD.

Reptiles.	Wormley.		Gulliver.	
	Length.	Breadth.	Length.	Breadth.
Tortoise (land)	1-1250	1-2200	1-1252	1-2216
Turtle (green)	. . .	. . .	1-1231	1-1882
Boa-constrictor	1-1245	1-2538	1-1440	1-2400
Viper	. . .	. . .	1-1274	1-1800
Lizard	. . .	. . .	1-1555	1-2743

Batrachians.	Wormley.		Gulliver.	
	Length.	Breadth.	Length.	Breadth.
Frog	1-1089	1-1801	1-1108	1-1821
Toad	. . .	. . .	1-1043	1-2000
Triton	. . .	. . .	1-848	1-1280
Proteus	. . .	. . .	1-400	1-727
Amphiuma tridactylum	1-358	1-622	1-363	1-615

Fishes.	Gulliver.	
	Length.	Breadth.
Trout	1-1524	1-2460
Perch	1-2099	1-2824
Pike	1-2000	1-3555
Eel	1-1745	1-2842
Lamprey	Circular.	1-2134
Nucleus	. . .	1-6400

Average Size of the Red Blood-Corpuscles.

Mammals.	Wormley.	Gulliver.	Mammals.	Wormley.	Gulliver.
Man	1-3250	1-3200	Rhinoceros	1-3649	1-3765
Monkey	1-3382	1-3412	Tapir	1-4175	1-4000
Opossum	1-3145	1-3557	Lion	1-4143	1-4322
Guinea-pig	1-3223	1-3538	Ocelot	1-3885	1-4220
Kangaroo	1-3410	1-3440	Mule	1-3760	
Musk-rat	1-3282	1-3550	Ass	1-3620	1-4000
Dog	1-3561	1-3532	Ground-squirrel	1-4200	
Rabbit	1-3653	1-3607	Bat	1-3966	1-4175
Rat	1-3652	1-3754	Sheep	1-4912	1-5300
Mouse	1-3743	1-3814	Ibex	1-6445	
Pig	1-4268	1-4230	Goat	1-6189	1-6366
Ox	1-4219	1-4267	Sloth	. . .	1-2865
Horse	1-4243	1-4600	Platypus (duck-billed)	. . .	1-3000
Cat	1-4372	1-4404	Whale	. . .	1-3099
Elk	1-4384	1-3938	Capybara	1-3164	1-3190
Buffalo	1-4351	1-4586	Seal	. . .	1-3281
Wolf (prairie)	1-3422	1-3600	Woodchuck	. . .	1-3484
Bear (black)	1-3656	1-3693	Musk-deer	. . .	1-12325
Hyena	1-3644	1-3735	Beaver	. . .	1-3325
Squirrel (red)	1-4140	1-4000	Porcupine	. . .	1-3369
Raccoon	1-4084	1-3950	Llama, long diam.	1-3201	1-3361
Elephant	1-2738	1-2745	Llama, short "	1-6408	1-6229
Leopard	1-4390	1-4319	Camel, long diam.	1-3331	1-3123
Hippopotamus	1-3560	1-3429	Camel, short "	1-5280	1-5876

Birds.	Wormley.		Gulliver.	
	Length.	Breadth.	Length.	Breadth.
Chicken	1-2080	1-3483	1-2102	1-3466
Turkey	1-1894	1-3444	1-2045	1-3598
Duck	1-1955	1-3504	1-1937	1-3424
Pigeon	1-1892	1-3804	1-1973	1-3643
Goose	. . .	. . .	1-1836	1-3839
Quail	. . .	. . .	1-2347	1-3470
Dove	. . .	. . .	1-2005	1-3369
Sparrow	. . .	. . .	1-2140	1-3500
Owl	. . .	. . .	1-1763	1-4076

The general conclusion reached by Professor Wormley is, "*that the microscope may enable us to determine with great certainty that a blood is* NOT *that of a certain animal and is* CONSISTENT *with the blood of man; but in no instance does it in itself enable us to say that the blood is really human, or indicate from what particular species of animal it was derived.*"

COMPARATIVE TABLE OF THE AVERAGE RESULTS OF MEASUREMENTS OF RED BLOOD CORPUSCLES OF MAMMALS.

Each column giving the average size (diameter) of the Corpuscles as obtained by various observers, expressed in fractions of the English inch, side by side with the common expression (roughly) in millimeters.

	Gulliver, 1845 and 1875.		Wormley, 1885.		C. Schmidt, 1848. Mallinin, 1875.		French Medico Legal Society, 1873, and Wilker.		Masson, 1885.		Hans Schmid, 1878.		Woodward, 1875.		Personal Observations.	
	In.	M. M.	In.	M. M	In.	M. M.	In.	M. M.	In.	M. M	In.	M. M	In.	M. M.	In.	M. M.
Elephant	1.2745	0.0092	1.2738	0 0093												
Great Anteater	1.2769	0.0088														
Walrus	1.2769	0.0088														
Sloth	1.2865	0.0086														
Ornithorynchus	1.3000	0.0081														
Whale	1.3099	0.0080														
Opossum	1.3557	0.0071	1 3145	0 0080												
Capybara	1.3190	0.0080	1.3164	0.0080												
Man	1.3200	0.0079	1.3250	0 0078	1.3300	0.0077	1.3257	0 0078	1.3257	0.0078	1 3412	0.0074	1.3092	0 0082	1.3200	0.0079
Seal	1.3281	0.0078														
Beaver	1.3325	0.0076														
Muskrat	1.3550	0.0072														
Porcupine	1.3369	0.0075														
Monkey	1.3412	0.0074	1 3382	0.0075												
Kangaroo	1.3440	0 0074	1 3410	0 0074												
Guinea Pig	1.3538	0.0071	1.3223	0.0079					1.3300	0 0077			1.3213	0.0079	1.3400	0 0075
Wolf	1.3600	0.0070	1 3422	0 0074											1.3450	0.0074
Dog	1.3532	0.0071	1.3561	0 0071	1.3636	0.0070	1.3485	0 0073	1 3577	0.0071	1 3846	0.0066	1 3246	0.0078	1.3580	0.0071
Rabbit-	1.3607	0.0070	1.3653	0 0070	1.3968	0.0064	1 3653	0 0069	1 3636	0.0070					1.3662	0.0069
Ass	1.4000	0.0063	1.3620	0 0070												
Rat	1.3754	0.0068	1 3652	0 0070	1 3968	0.0064					1 5000	0 0051				
Bear	1.3693	0.0070	1.3656	0 0069												
Mouse	1.3814	0.0067	1 3743	0.0067	1 5000	0 0051										
Mule			1.3760	0 0067												
Squirrel	1.4000	0.0064	1.4140	9.0061												
Ox	1.4267	0.0060	1.4219	0.0060	1.4354	0 0058	1.4545	0.0056	1.4237	0.0060	1.4695	0.0054			1 4200	0.0060
Pig	1.4230	0.0060	1 4268	0.0059	1.4098	0 0062	1.4098	0 0062	1.4098	0.0062	1.4098	0.0062			1.4250	0.0060
Horse	1 4600	0.0055	1 4243	0,0059	1.4464	0 0057	1.4545	0 0056							1 4310	0.0059
Cat	1 4404	0.0058	1 4372	0 0058	1.4545	0.0056	1.3922	0.0065	1.4440	0.0057						
Sheep	1 5300	0.9048	1 4912	0.0951	1 5649	0.0045	1 5076	0 0050	1.4464	0.0057	1.6060	0.0042			1.5000	0.0051
Goat	1 6366	0.0040	1 6189	0,0041	1.6369	0.0040	1.5525	0.0046							1.6100	0.0042

Gulliver's Tables

The micrometry of Gulliver's tables has been very generally accepted as standard, although taken a good many years ago and with imperfect instruments. His studies extended over thirty years, and embraced 800 animals.

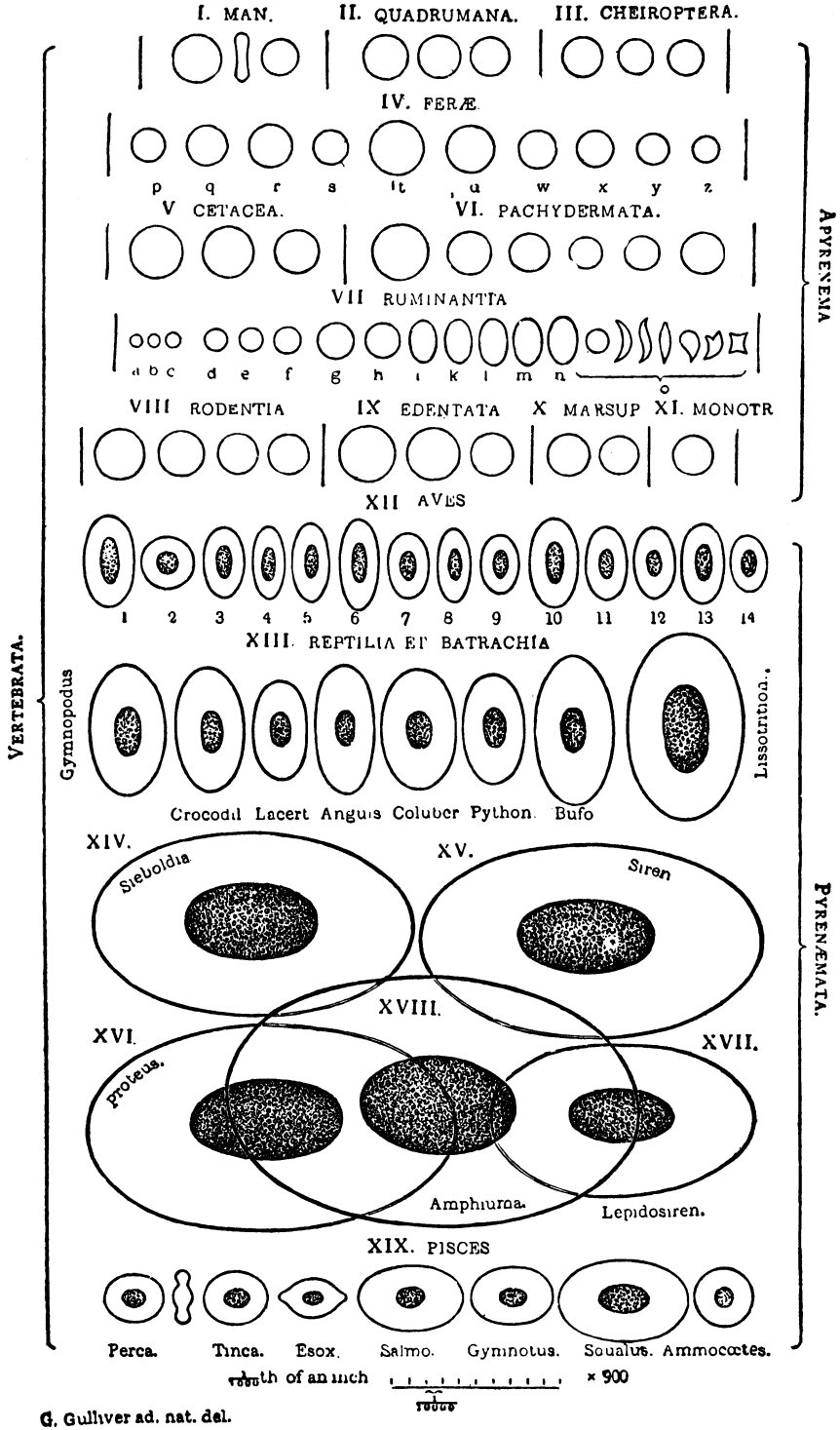
The object of his work was a biological study to prove that the blood corpuscle was the most reliable means of the classification of species in animals.

His measurements were made almost half a century ago, and he did not claim for them exactness of micrometry, but he only claimed for them "*that the relative value of the measurements, though probably not unexceptionable, may be entitled to more confidence as a fair approximation to the truth.*"

NOTE: EXPLANATIONS OF THE FIGURES UPON GULLIVER'S PLATES.—The red blood corpuscles are all done to one and the same scale, representing $\frac{1}{1000}$ of an English inch, and each one of the ten divisions $\frac{1}{10000}$ of an inch. (*Vide* foot of page.) Only corpuscles of the average size and regular shapes are given, and they are all magnified to the same size, 900 diameters. The descriptive tables explain the plate.

PLATE IV.

Gulliver's micrometry of red blood corpuscles, all to a uniform scale.



G. Gulliver ad. nat. del.

A —VERTEBRATA APYRENÆMATA (SEE PLATE IV)

I HOMO (MAN)..... 1-3200

*1. Corpuscles lying flat

2. The same on edge

3. Membraneous base of same after removal by water of coloring matter; it shows diminution in diameter on account of acquired spherical shape.

II. QUADRUMANA (MONKEYS.)

4. Simia troglodytes (Chimpanzee)..... 1-3412

5 Ateles ater. (Black-faced spider monkey)..... 1-3602

6 Lemur anguanensis..... 1-4003

III CHEIROPETERA (BATS)

7. Cynonycteris collaris (fruit bat)..... 1-3880

8. Vespertilio noctula (large bat)..... 1-4404

9 Vespertilio pipistrellus (common bat)..... 1-4324

IV FERÆ (BEASTS OF PREY.)

(p) 10 Sorex tetragonurus (shrew)..... 1-4571

(q) 11 Ursus labiatus (lipped bear)..... 1-3728

(r) 12 Bassaris astuta civet cat)..... 1-4033

(s) 13 Cercoleptes caudivolvulus (kinkajou)..... 1-4573

(t) 14 Trichechus rosmarus (walrus)..... 1-2769

(u) 15 Canis dingo (dog, Australian)..... 1-3395

(w) 16 Mustella zorilla (weasel)..... 1-4270

(a) 16 Felis leo (lion)..... 1-4322

(b) 16 Felis leopardus (leopard)..... 1-4319

(x) 17 Felis tigris (tiger)..... 1-4206

(y) 18 Paradoxurus pallasii (Pallas paradoxure)..... 1-5485

(z) 19 Paradoxurus bondar (Bondar paradoxure)..... 1-5693

(a) 19 Hyena striata (striped hyena)..... 1-3735

V. CETACEA (WHALES.)

20. Balæna (boops—whale)..... 1-3099

21. Delphinus globiceps (caing—whale)..... 1-3200

22. Delphinus phocæna (porpoise)..... 1-3829

VI. PACHYDERMATA.

23. Elephas indicus (elephant)..... 1-2745

24. Rhinoceros indicus (rhinoceros)..... 1-3765

25. Tapirus indicus (tapir)..... 1-4000

26. Equus caballus (horse)..... 1-4600

27. Dicotyles torquatus (peccary)..... 1-4490

28. Hyrax capensis (Cape hyrax)..... 1-3308

VII. RUMINANTIA (RUMINANTS.)

(a) 29. Tragulus javanicus, (Javan chevrotain, musk deer)..... 1-12325

* Through an oversight, some of the figures are not marked upon the plate.

) 30	Tragulus meminna (Indian chevrotain)		1-12325
(-) 31.	Tragulus Stanleyanus (Stanleyan chevrotain)		1-10825
( ) 32	Cervus nemorivagus (deer)		1-7060
(e) 33.	Capra Caucasica (Caucasian ibex)		1-7045
(f) 34.	Capra hircus (domestic goat)		1-6366
(g) 35.	Bos urus (represented by Chillingham cattle)		1-4267
(h) 36	Camelopardalis giraffa (giraffe)		1-4571
(i) 37	Auchenia vicugna (vicuna)	L. D.	1-3555
		Sh. D.	1-6587
(k) 38.	Auchenia paca (alpaca)	L. D.	1-3361
		Sh. D.	1-6229
(l) 39	Auchenia glama (llama)	L. D	1-3361
		Sh. D.	1-6229
(m) 40	Camelus dromedarius (single hump camel	L. D.	1-3254
		Sh. D.	1-6931
(n) 41	Camelus bactrianus (double hump camel)	L. D.	1-3123
		Sh. D.	1-5876
(o) 42.	Cervus Mexicanus* (deer—Mexican)		1-5175

VIII. RODENTIA (RODENTS).

43.	Hydrochœrus capybara (capybara)	1-3190
44.	Castor fiber (beaver)	1-3325
45.	Sciurus cinereus (squirrel)	1-4000
46	Mus messorius (harvest mouse)	1-4268

IX EDENTATA

47.	Myrmecophaba jubata (ant eater)	1-2769
48	Bradypus didactylus (sloth)	1-2865
49.	Dasypus villa (armadillo)	1-3315

X MARSUPIALIA

50	Phascolomys (wombat)	1-3456
51.	Hypsiprymnus setosus (kangaroo rat)	1-4000

XI MONOTREMATA

52	Echidna histrix (echidna)	1-3840

B.—VERTEBRATA PYRENÆMATA

XII AVES (BIRDS)	L D	SH D
1. Struthio camelus (ostrich)	1-1649	1-3000
2 The same made round and deprived of color by water		
3 Vanga destructor (East India shrike)	1-2019	1-3892
4 Lanius excubitor (great grey shrike)	1-1989	1-5325
5 Bubo virginianus (horned owl)	1-1837	1-4000
6 Syrnea nyctea (snowy owl)	1-1555	1-4042
7 Columba rufina (rufous pigeon)	1-2314	1-3329
8. Columba migratoria (wild pigeon)	1-1909	1-4626
9. Dolichonyx oryzivorus (rice bird)	1-2400	1-4167

* The only animal in which the red blood corpuscles present a variety of shapes in the same individual —Gulliver

10. Buceros rhinoceros (rhinoceros hornbill)... 1-1690—1-3230
11. Psittacus augustus (August amazon)..... 1-2085—1-3606
12. Phasianus superbus (barrel-tailed pheasant) 1-2128—1-3587
13. Pelecanus onocrotalus (white pelican)..... 1-1777—1-3369
14. Trochilus sp. (humming bird)..... 1-2560—1-4000

Figures XII, XIV, XVI, XVII and XVIII represent red blood corpuscles of Reptilia and Bactrachia; while under figure XIX. those of the fishes are given. In all these figures the names of the animals are inserted upon the plate, and they do not require any comment at this place. It is evident that the blood corpuscles of the Amphiuma are so large that they can be perceived by the naked eye.

Welcker's Tables.

The measurements by Welcker are very exact measurements of certain animals, and I am enabled to give the following table of a few of his mean measurements:

For man, on an average, expressed in millimeters:

	Min.	*Max.*
Diameter of disk, 0.00774.....	0.00640	0.00860
Greatest thickness of the disk.....		0.00190

These measurements were made on fresh blood or blood dried in thin layers on glass.

His mean table is as follows: (Zeitschrift fur rationelle Medecin, 3 R. Band, * * * p. 259; Stricker's Manual of Histotomy, article "Blood," by Alex. Rollett, p. 267 *et seq.*)

I. CIRCULAR CORPUSCLES.

Dog	0·0073
Cat	0·0065
Rabbit	0·0069
Sheep	0·0050
Goat (old)	0·0041
Goat (8th day)	0·0054
Moschus Javanicus	0·0025
Petromyzon mari	0·0150
Ammocœt branch	0·0117

II. ELLIPTICAL CORPUSCLES.

a, Long diameter; *b*, short diameter.

	a.	*b*.
Lama	0·0080	0 0040
Pigeon (old)	0·0147	0·0065
Pigeon (fledged)	0·0137	0·0078
Pigeon (fledged)	0·0126	0·0078
Duck	0·0129	0·0080
Fowl	0·0121	0·0072
Rana temporaria	0·0223	0·0157
Rana temp. (dry)	0.0214	0·0156
Triton Cristatus	0·0293	0·0195
Proteus (1 and 2)	0·0582	0·0337
	0·0579	0·0356
Sturgeon	0·0134	0·0104
Cyprinus Alburn	0·0131	0·0080
Lepidosiren Annectens	0·0410	0·0290

The method employed by Welcker has been thus described:

"He employed a very short cylinder of plaster of Paris, the proportion of the radius to the height of which was estimated to correspond with the dimensions of the blood corpuscles; and by scooping out the surface and rounding off the edge he obtained a curvature of the surface which, to the eye, (!) was similar to that of the blood corpuscles. He thus determined the mean volume of human blood red corpuscles to be .000,000,072,217 of a cubic millimeter. Welcker, moreover, carefully lined the interior of this model, which was 5,000 times larger than the corpuscles, with paper of uniform thickness, then weighed the paper used, and compared this with the weight of a known superficial measure of the same paper. From the data thus obtained he estimated that the superficies presented by a blood corpuscle amounts to 0.0,001,280 square millimeters. It is sufficently obvious that these numbers have only a coarsely approximate value."

The most extended tables of the measurement of corpuscles are to be found in Milne Edwards. (Lecons sur la Physiologie et l'Anatomie Comparie, Paris, 1857, T. 1, p. 41.)

Professor Wormley's Tables.

The following tables of the average or mean size of the normal red blood corpuscles of different animals were made by Professor Theodore G. Wormley, in general, from blood after the corpuscles had been dried in very thin layers, but in some instances while the blood was still fluid, and is taken, by his permission, from his work, "Micro-Chemistry of Poisons," published by J. B. Lippencott & Co., Philadelphia, in 1885.

These averages he has expressed in vulgar fractions of an English inch, and are the mean of two or more series of measurements, and in some instances of the blood of different individuals of the same species.

Professor Wormley has contrasted his measurements with those of Professor Gulliver, as published in the proceedings of the Zoological Society of London, June 15, 1875, and also in Hewson's works, at page 237 *et seq.*

It will be observed, on a scrutiny of these tables, that there is a marked difference between these observers in the diameter of the corpuscles of the opossum, amounting to $\frac{1}{27152}$ of an inch, and a similar discrepancy in those of the guinea-pig.

Professor Formad challenges the correctness of Professor Wormley's measurements and those of Dr. Woodward (1.3213). Professor Formad says (Comparative Studies of Mammalian Blood, p. 18), that he examined ten different animals, making ten preparations in each case and measuring 100 corpuscles from each animal, and found that the mean diameter was $\frac{1}{3400}$ of an inch in every 1,000 corpuscles.

His results were confirmed by Drs. J. L. Hatch, A. J. Plumer, and Henry Wile, and by the celebrated Dr. Richardson, and they approximate nearer those of Gulliver.

Dr. Formad also says that Wormley's observations were of the corpuscles of one wild guinea-pig (*Cavia aperia*), while Formad's examination was of the domestic (*Cavia cobaya*), and that while Woodward's measurements were of the blood of the latter animal, that his micrometry was unreliable, in that he only examined 401 corpuscles, all from one drop of blood and from a single individual.

I take pleasure, also, in quoting Professor Wormley's observations of old blood stains from his "Micrometry of Poisons," with his table and explanatory marks.

COLLECTIVE RESULTS OF SOME OF THE SERIES OF MEASUREMENTS OF RED BLOOD CORPUSCLES IN BLOOD STAINS AND IN EXPERIMENTALLY DRIED BLOOD

Normally shaped (bi-concave, disc-like) corpuscles only being measured.

Source of Blood.	Upon what Substance.	Age of Stain.	Condition, or how Prepared.	Number of Individuals Examined.	Number of Preparations Made.	Reagents used for Remoistening.	Time of effect of Reagents.	Per cent. of Measurable Corpuscles in each preparation.	Total Number of Corpuscles measured.	Average Diameter in inch.	Normal Diameter of Fresh Blood.
Man.	Knife and Glass.	2 days.	Rapidly dried	10	30	*K. O. H.	5 to 30 min'ts.	20 to 50	1000	1-3260	1-3200
Man.	Cloth	7 days.	Slowly dried	2	10	K. O. H.	½ hour to 2 dys	5 to 20	250	1 3300	1-3200
Man.	Wood and Linen.	10 days.	Slowly dried	4	20	*M. F	2 hrs to 2 dys.	5 to 15	200	1-3300	1-3200
Man.	Paper	14 days.	Decomposed from moisture.	1	10	M. F.	3 days.	not measurable.			
Man.	Knife.	2 years.	Well dry preserved	1	10	K. O. H. & M. F.	2 days.	10 to 50	400	1-3240	1-3200
Man.	Stone	6 years.	Well preserved	1	30	K. O. H. & M. F.	3 days.	5 to 20	500	1-3320	1-1320
Guinea-pig	Glass	7 days.	Rapidly dried stains	6	18	K. O. H. & M. F.	1 to 2 days.	10 to 40	500	1-3460	1-3400
Wolf	Glass	7 days.	Rapidly dried stains	1	50	K. O. H. & M. F.	1 to 2 days.	5 to 20	1000	1-3450	1-3450
Dog.	Cloth	7 days.	Rap dly dried stains	4	12	K. O. H. & M. F.	1 to 2 days.	5 to 50	500	1-3650	1-3580
Rabbit	Knife	7 days.	Rapidly dried stains	10	30	K. O. H. & M. F.	1 to 2 days.	5 to 50	1000	1-3700	1-3662
Ox.	Cloth	7 days.	Rapidly dried stains	10	30	K. O. H. & M. F.	1 to 2 days.	20 to 40	1000	1-4240	1-4200
Sheep.	Glass	7 days.	Rapidly dried stains	3	9	K. O. H. & M. F.	1 to 2 days.	50	500	1-5060	1-5000
Goat	Knife	7 days.	Rapidly dried stains	3	9	K. O. H. & M. F.	1 to 2 days.	50	500	1-6200	1-6100

*"K. O. H" stands for 33 per cent. Solution of Caustic Potash. "M. F." for Muller's fluid.

Examination of Old Blood-Stains.

Animal.	Age of Stain.	Remarks.	Average.	Fresh Blood.
(1) Human . .	2 months old.	Stain, unknown.	1-3358th inch.	1-3250th inch.
(2) " . .	2½ " "	Stain.	1-3236th "	" "
(3) " . .	3 " "	"	1-3384th "	" "
(4) " . .	19 " "	Clot.	1-3290th "	" "
(5) Elephant . .	13 " "	"	1-2849th "	1-2738th "
(6) Dog . . .	4 " "	Trace of stain, unknown.	1-3626th "	1-3561st "
(7) Rabbit . .	18 " "	Clot.	1-3683d "	1-3653d "
(8) Ox	16 " "	Stain.	1-4544th "	1-4219th "
(9) "	32 " "	Stain, unknown.	1-4495th "	" "
(10) "	4½ years "	Clot.	1-4535th "	" "
(11) Buffalo . .	18 months "	"	1-4312th "	1-4351st "
(12) Goat . . .	17 " "	Stain.	1-5897th "	1-6189th "
(13) Ibex . . .	18 " "	Clot.	1-6578th "	1-6445th "

In the case of the human blood, No. 1, two months old, the deposit was in the form of a thin stain on muslin, and its nature, other than that it was mammalian blood, was unknown at the time of examination. The corpuscles were readily found, and two series of thirty corpuscles each were measured. In the human blood two and a half months old, fifty corpuscles, ranging from 1-3125th to 1-3448th of an inch, were measured.

The blood-stain of the dog, No. 6, was prepared by Dr. Frankenberg, and consisted of a single stain so minute as to be barely visible to the naked eye: its nature at the time of the examination was unknown. In this instance only fifteen corpuscles were measured.

In the ox blood four and half years old, the corpuscles were rather readily obtained, and two closely concordant series of measurements were made.

In examinations of this kind it should be borne in mind that certain portions of a deposit may fail to yield satisfactory results, whilst from other portions the corpuscles may be readily obtained.

The number of red corpuscles in a cubic millimeter of blood of a healthy man is determined to be about 5,000,000, from which the number in a gallon, quart, pint, or ounce can be computed.

It has also been as clearly demonstrated that the relative quantity of corpuscles and plasma or serum (*Liquor sanguinis*) in a hundred volumes of blood is thirty-six volumes of corpuscles and sixty four volumes of plasma. Thus the volume of blood is $\frac{64}{100}$ plasma or serum and $\frac{36}{100}$ corpuscles. (See Professor Stricker's Manual of Histology, article "Blood," by Alexander Rollett, translated by Henry Power, of London, chap. 13, p. 269).

Variations in Size of the Red Corpuscle.

Professor Ewell has shown by experiments that many diseases alter the size of the corpuscles, especially microcythæmia, and that they also vary in health.

I have submitted, with his permission, three tables (I, II, and III), showing the result of the measurement of 650 corpuscles of the fresh blood of Professor Ewell, then being in good health.

These diagrams were first drawn in rectangular coördinates.

The horizontal divisions, unless otherwise noted, represent each one division of the eye-piece micrometer. The vertical divisions represent the number of corpuscles, each division, unless otherwise noted, representing one corpuscle. The point of origin at the left is, for want of space, not shown on the diagrams. The curved lines, representing the number of corpuscles, are drawn with the point of origin as their common center and with radii equaling the number of divisions of the micrometer subtended by them respectively. The curves, therefore, represent on a large scale the relative size of the corpuscles.

A brief statement of the methods employed in reaching the results that have been generally accepted as standard and reliable mean measurements will throw light upon the subject, and at the same time illustrate the views of those who differ so widely as to the reliability of attainable results. The methods employed by observers must have great weight in determining the value and accuracy of results.

Formad's Method.

Place a drop of blood upon a slide and quickly draw the edge of another slide across the field in such a manner that the corpuscles become as evenly distributed as possible between the slides.

Then use a good microscope, provided with a homogeneous immersion lens, and two micrometers, the one a stage piece, the other an eye-piece micrometer.

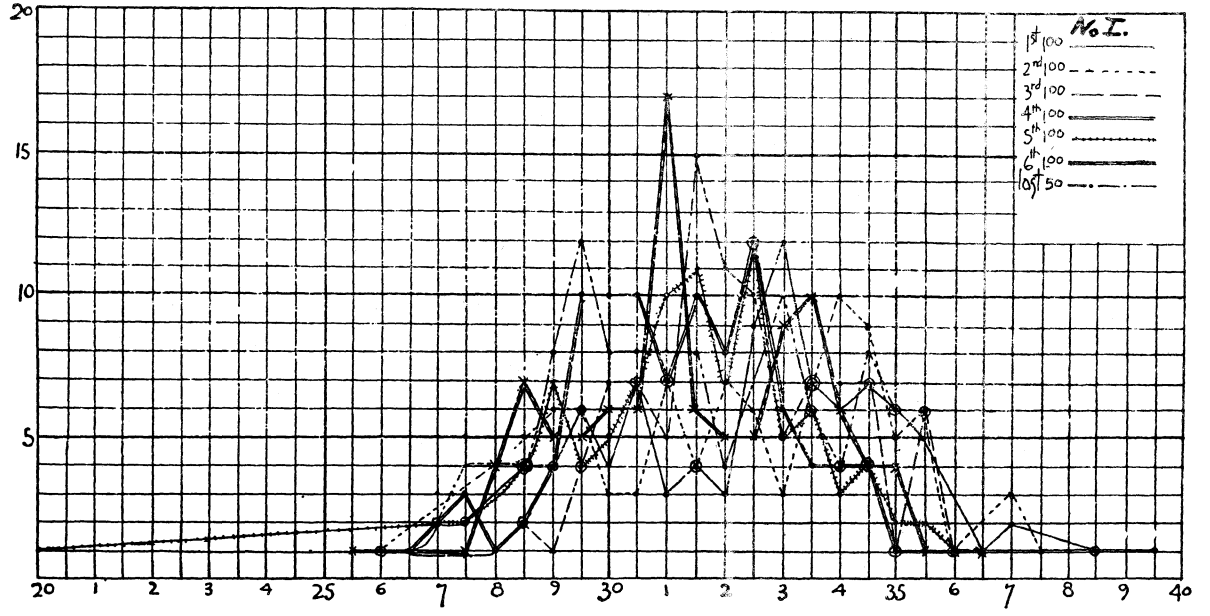
The stage micrometer is used to establish the correct value of the lines ruled on the micrometer, and consists of a glass slide ruled to a scale either in mm. or fractions of an inch. The English standard slides are ruled by a series of lines $\frac{1}{100}$ of an inch apart, one of these divisions having further subdivisions into thousandths of an inch, and in some still smaller subdivisions.

Of course all depends upon the absolute correctness of these rulings, and they should be carefully tested before using.

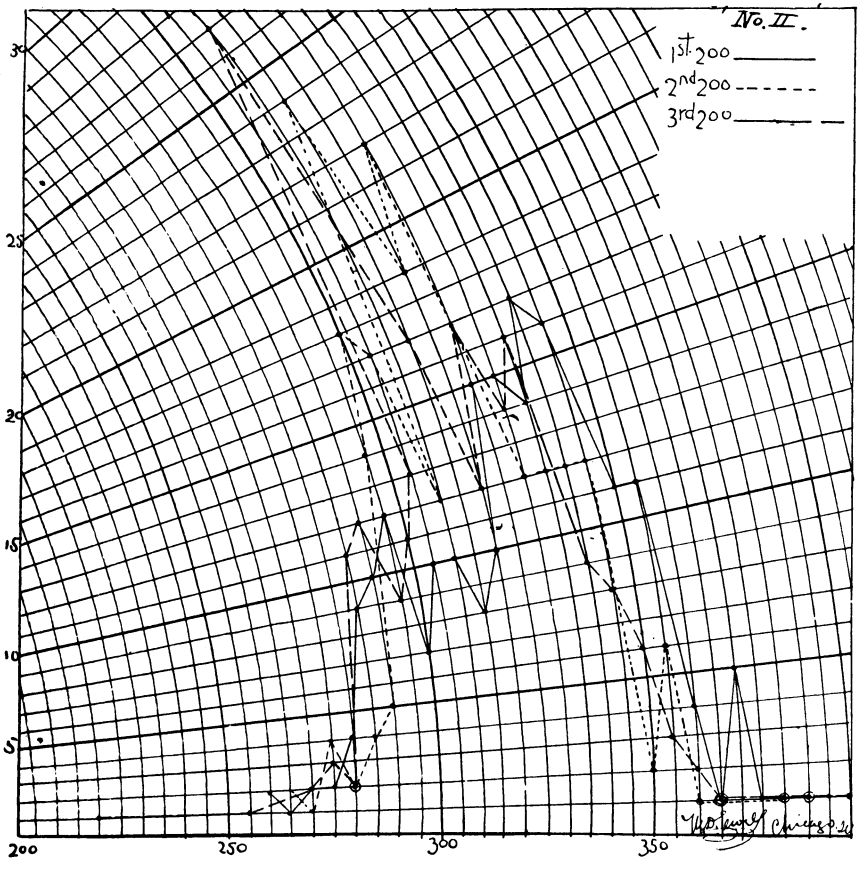
The safest way is to use a high power, compare one division with another carefully, and note the discrepancies, using only such as are exact and precisely correct. The eye-piece micrometer is a slip of

Six hundred and fifty corpuscles from M. D. Ewell. Spencer 1-10 and Bauch & Lomb Amplifier. 1 div. of filar micrometer = .000001 inch.

Mean of 1st 100	=.000322	=8.18	mikrons.	Mean of 6th 100	=.000318	=8.05	mikrons.
" 2d "	=.000324	=8.23	"	" last 50	=.000313	=7.95	"
" 3d "	=.000321	=8.15	"	" 650 corpuscles (corrected)	.000316	=8.03	"
" 4th "	=.000315	=8.99	"	Largest corpuscles of the 650	=.000393	=9.98	"
" 5th "	=,000316	=8.03	"	Smallest " " "	=.000198	=5.03	"



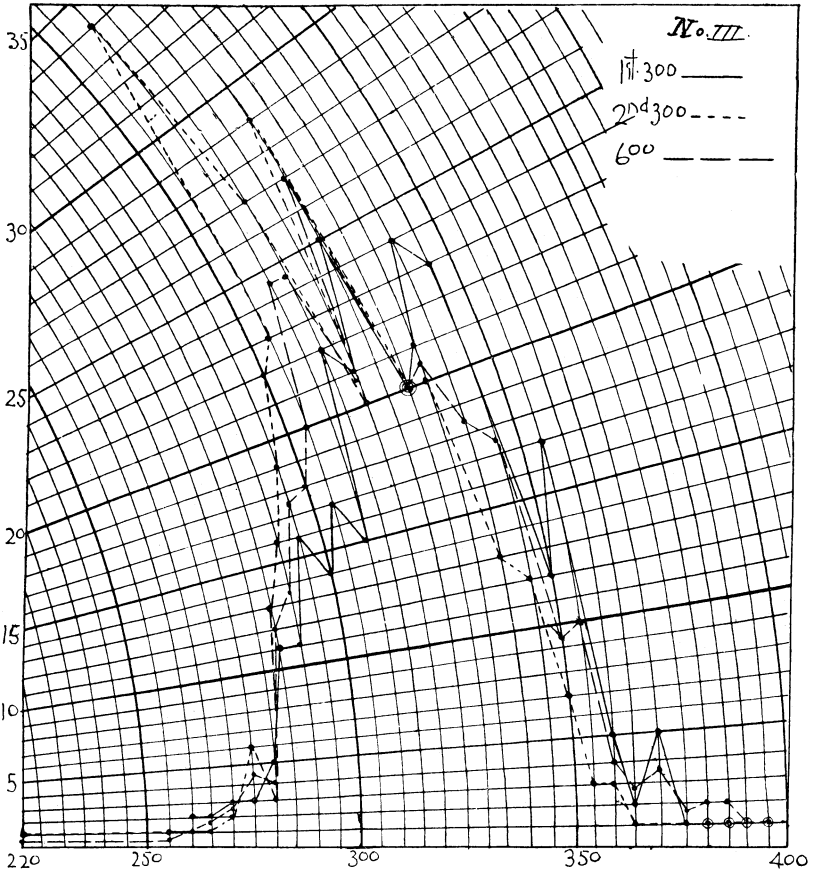
Each vertical space = one corpuscle, except in case of the last 50, where two spaces = one corpuscle.
Each horizontal double space = 10 divisions of the micrometer.



No. II. The first 600 corpuscles of the 650 platted in No. I. Spencer 1-10, etc.

1st 200 mean	=.000323 inch		=8.20 mikrons.
2d "	=.000318 "		=8.01 "
3d "	=.000317 "		=8.05 "

Each space horizontally = 5 divisions of the micrometer.
Each space vertically = 1 corpuscle.



No. III. The same 600 red corpuscles. Spencer 1-10, etc.

1st 300 mean..... .....=.000322 inch..... =8.18
2d " .....=.000316 " .....=8.01
600 mean..... .....=.000319 " ....=8.10

Each horizontal space = 5 divisions of the micrometer.
Each vertical space = 2 corpuscles.

glass with fine lines ruled to a uniform scale, which fits into the eye-piece of the microscope.

When in position the stage micrometer notes how many of the divisions on the eye-piece micrometer are required to fill one of the divisions of the stage micrometer. For example, if a $\frac{1}{12}$ Zeiss' homogeneous immersion lens is used, and under this amplification the $\frac{1}{100}$ of an inch division of the stage and scale covers exactly twenty places in the eye-piece scale, then each division of the eye-piece micrometer will be equal to the $\frac{1}{2000}$ of an inch.

The higher objectives will increase the value of the divisions; lower ones will decrease them, but under all circumstances the same conditions must be observed.

When thus adjusted, bring the slide containing the drop of blood into focus under the eye-piece micrometer, previously adjusted, and observe the number of divisions or fractions of a division of the eye-piece micrometer that a corpuscle may occupy.

For example, if it should fill exactly four spaces, then its value would be under $\frac{1}{2000}$ of an inch; standard, $\frac{4}{2000}$ or $\frac{1}{5000}$ of an inch.

Measure one hundred corpuscles in this manner, taking actual measurements and noting them and from different slides that have been tested, and then take an average of the result. The measurements should be made only of perfectly round biconcave corpuscles and carefully recorded. All small or crenated blood corpuscles should not be counted.

Dr. Carl Seiler, of Philadelphia, introduced the micrometry of blood corpuscles from photographic negatives, which has also been done by Dr. Woodward, of the United States Navy.

The plan is to mount the blood directly upon a glass-stage micrometer and to photograph them with any desired amplification, both blood and micrometer appearing sharply defined in the picture. The measurements are then made directly upon the negative. (Formad's Comparative Studies of Mammalian Blood, pp. 7 and 8.)

Note.

At the discussion of this paper before the Medico-Legal Society the consensus of opinion favored the following propositions:

1. That there was no great difficulty in distinguishing between human blood and that of birds, fishes, and amphibia generally.

2. That by careful and competent observers, with instruments of high power, a reliable discrimination could be made between human blood and

the blood of mammals when the size of the red blood corpuscles was much smaller than that of man, notably the ox, the horse, the goat, the sheep, the pig, and most mammals.

3. That the blood of the dog, the rabbit, and the guinea-pig so nearly resembles human blood in the size or diameter of the red corpuscles that it was exceedingly difficult, if not impossible, to distinguish between them, and divided opinions upon this subject exists among observers, Professors Reese, Formad, Reyburn, and others claiming that by the employment of high powers, up to 10,000 diameters, the difference in diameter becomes so great when thus magnified as to make it apparent in all mammals except the guinea-pig and opossum; while Professor Ewell and others deny that the results of these investigations are such as to make it certain and absolute when, in doubtful cases, human life is at stake.

4. All concur in the safety of the careful microscopist, who asserts positively "*that the blood examined is consistent with human blood,*" if unwilling to state positively that it is such, or who agrees with the dictum of Professor Wormley in his masterly treatise, that "*the microscope may enable us to determine with great certainty that a blood is not that of a certain animal and is consistent with the blood of man.*" Although some might agree and some dissent from the same author's assertion, added to the above quotation: "*but in no instance does it in itself enable us to say that the blood is really human or indicate from what peculiar species or animal it was derived.*"